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SPECTRAL INFORMATION EXTRACTION FROM MULTIBAND PHOTOGRAPHS

[redacted] STAT

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SPECTRAL INFORMATION EXTRACTION FROM MULTIBAND PHOTOGRAPHS

Some important features of [redacted] multiband information extraction technique are illustrated by the accompanying pictures of a test scene set up in the laboratory. This example illustrates the use of spectral characteristics for contrast enhancement in a situation in which no single band contains sufficient information for "target" discrimination, and also illustrates the importance of suppressing or eliminating brightness differences in order to fully utilize the spectral information contained in multiband records. STAT

The scene contains an array of squares of different densities consisting of small tiles that had been painted different shades of gray, using two kinds of paint. Mixtures of black and white pigments in different proportions were used for the background tiles and mixtures of white with a special visually gray paint, prepared from yellow, cyan and magenta pigments, for the border tiles and lettering. Photographs were made in five different spectral bands within the visible spectrum, thus restricting the range of wavelengths used to those readily detected and distinguished by the human eye.

Three new images, or derived bands, were obtained from the original bands by combining positives and negatives of the original photographs, developed to the gammas specified by the output of a digital computer that was programmed to accept density measurements on the original photographs as input data and to provide the optimum combination of these photographs for contrast enhancement based on spectral differences. Each of the three derived bands extracts different spectral information from the original bands, the first containing the largest fraction of the total information, the second the next largest fraction, etc.

The illustrations presented include reproductions of:

1. An Ektacolor print and a color display prepared using the three derived bands as separation negatives,

2. The original five bands and a conventional photograph on Plus-X Pan film,

3. The first derived band, which was used as the green-magenta record in preparing the color display, and

4. The spectral curves of the painted tiles used to prepare the tile array.

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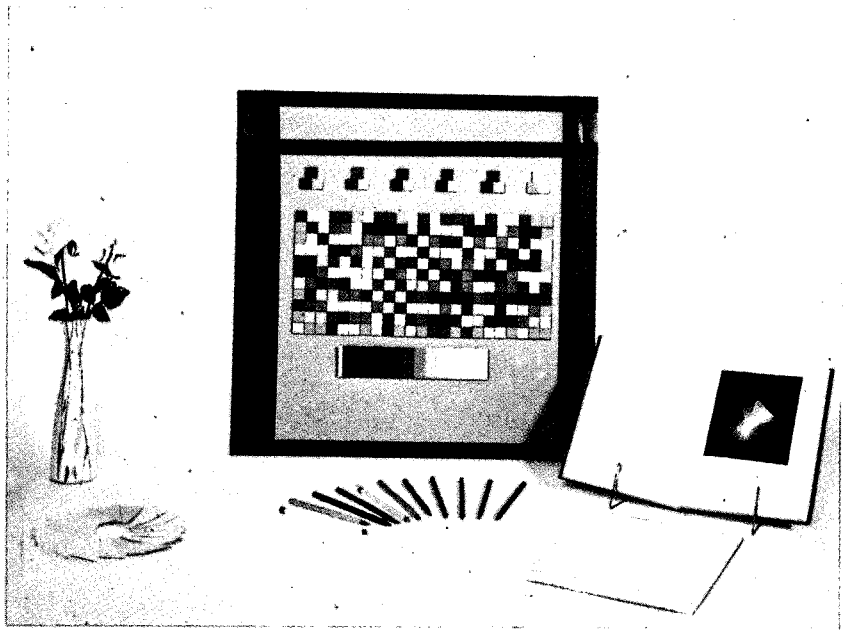
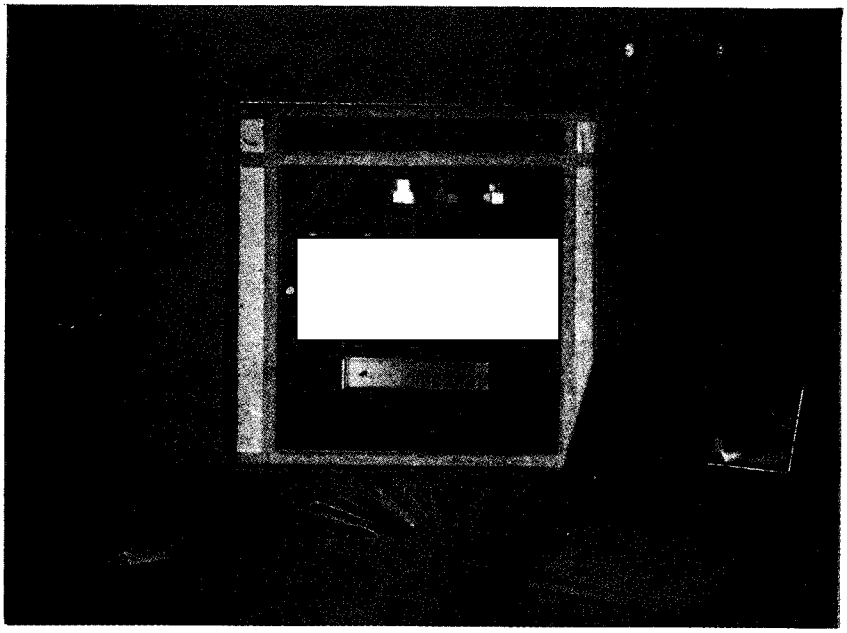
SPECTRAL INFORMATION EXTRACTION FROM MULTIBAND PHOTOGRAPHS



Ektacolor photograph of laboratory scene showing array of tiles painted with various mixtures of gray and white paint. Two kinds of gray paint were used that were matched as to color but differed in spectral characteristics.



Spectral information extracted from photographs in five spectral bands. Contribution of each band is indicated by the way the black identification number in the upper right hand corner of each original band photograph is reproduced in the final color display.

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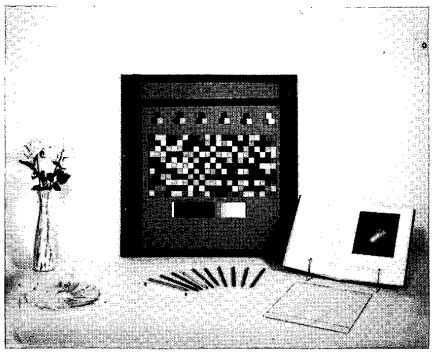
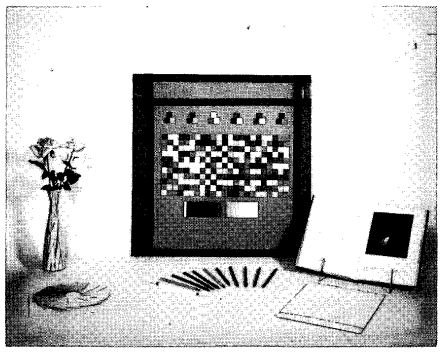
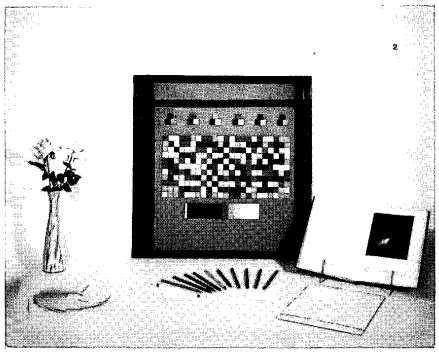


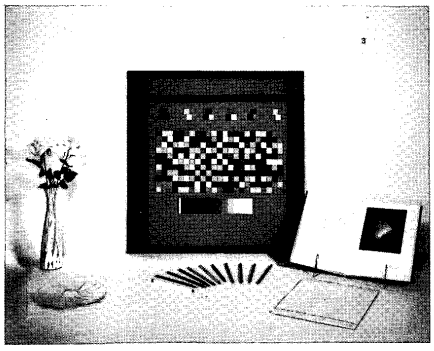
Plus-X Pan



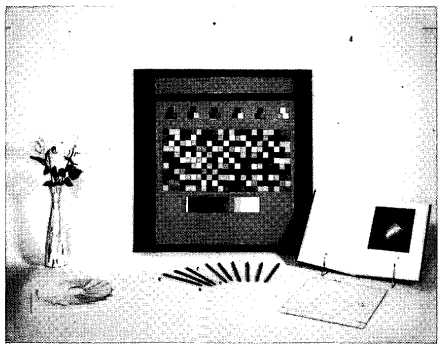
400-440 nm



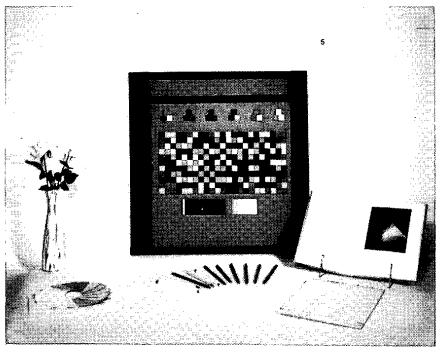
450-490 nm



500-530 nm



545-585 nm



590-620 nm

Panchromatic photograph and five-band spectral photographs of still life scene.

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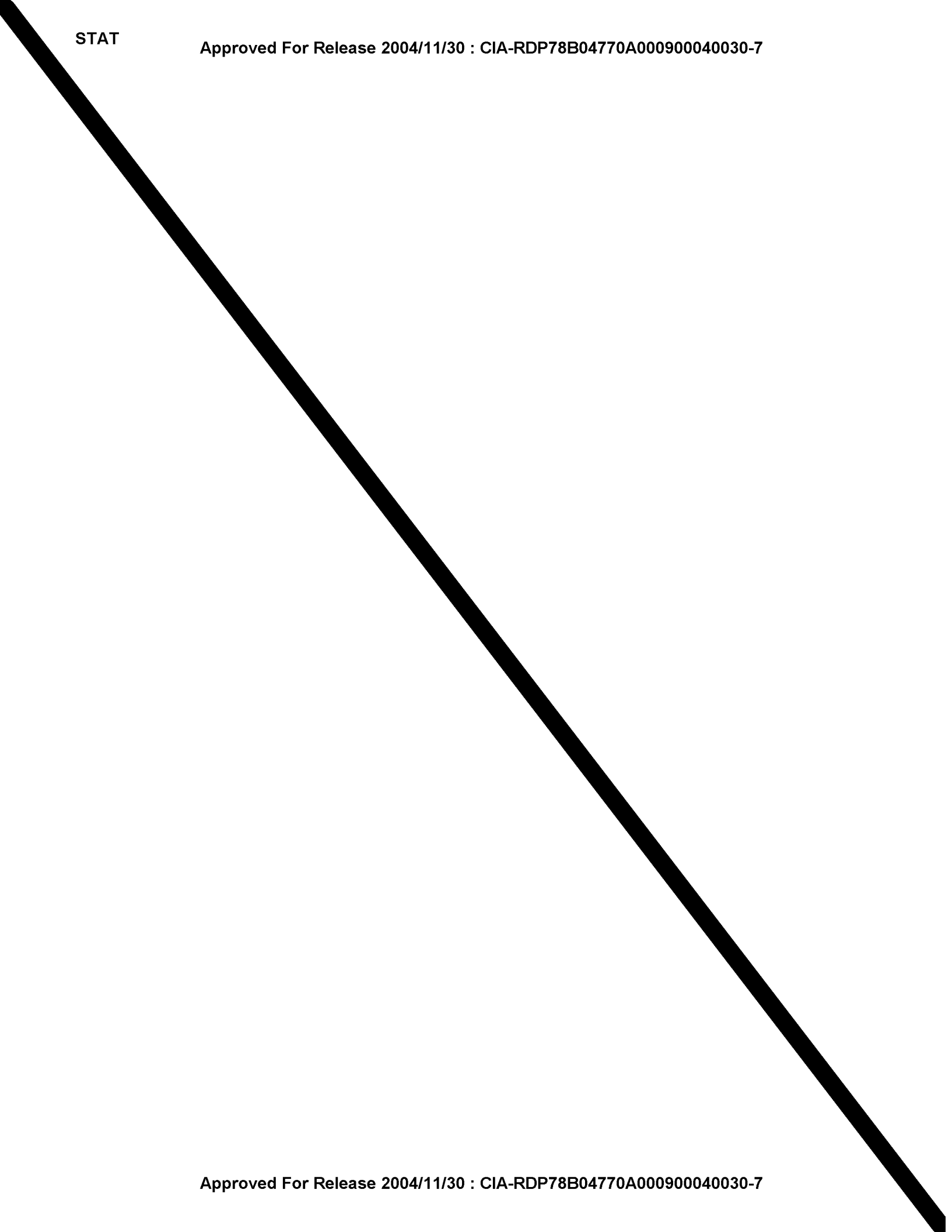

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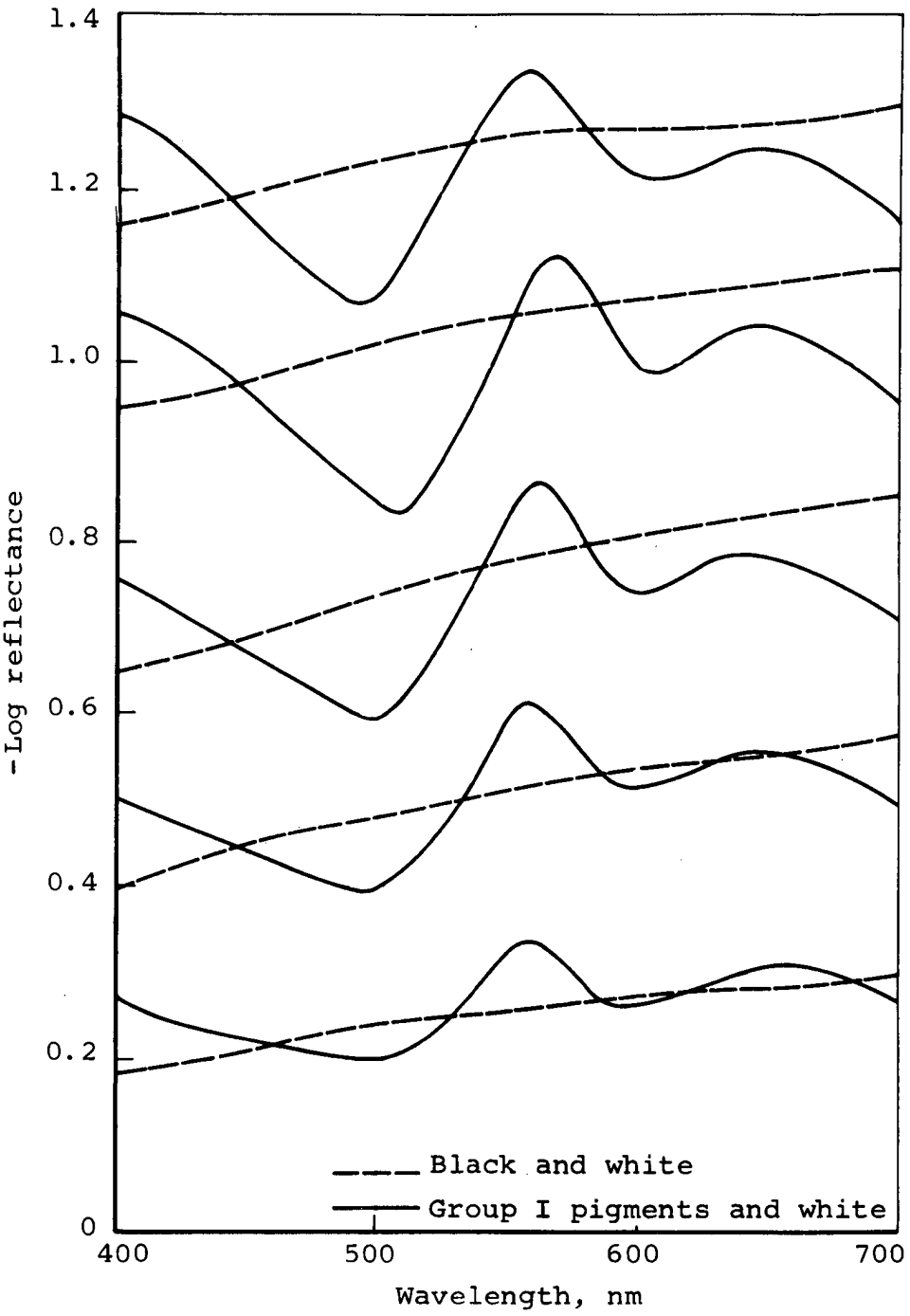

Metamers from mixed pigments.

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APPENDIX C

MULTIGATE PROJECTION VIEWER

C-1 TECHNICAL DISCUSSION

Additive color projection can be achieved by a variety of techniques which are based principally on the following:

1. Off-axis convergent projection
2. Coaxial superposition of multiple images, using beam splitters, rotating mirrors, etc.

Each system has certain advantages which must be weighed against its own peculiar disadvantages. The off-axis system requires an array of lenses placed closely together (Fig. C-1). In order to effect superposition, some or all of the lenses must project a target at different field angles to a common point on the screen. When the film width is about the same dimension as the lens cell diameter, this is not too serious a problem. With increased film sizes, however, field angle does become a problem for accurate image registration because of the physical limitation of packing the film transport systems. Even using a mirror system near the battery of lenses to separate the transport systems runs into difficulty when the number of projection gates reaches about four.

No matter what sort of ingenious packaging is devised, the inescapable fact remains that each lens is still attaining superposition in an off-axis condition. Lens distortions and other abberrations will cause a less than ideal registration of images which very often will display undesirable color fringes and size differences. Sometimes this can be overlooked, particularly in color-coded data display systems. Even in many conventional

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three-color additive projections of an aerial scene the eye tends to ignore many anomalies which exist due to color fringing and distortion. If the color projectors are flickered, however, the lack of registration often becomes very apparent. A system which is designed for the detection of very subtle color differences, while maintaining a high resolution level, would not be able to tolerate the limitations of the off-axis convergent projection system.

The system which will produce the most faithful registration of images is the coaxial projection system (C-2). Beam-splitting devices such as neutral reflecting-transmitting mirrors or color selective dichroics are used with the effect that all the various optical systems share one common optical axis.

Dichroic beam splitters make efficient use of the incident light but are limited to a predetermined pair of colors. This approach then does not offer the flexibility of color selection found with neutral beam splitters combined with interchangeable filters.

Neutral beam splitters appear to have characteristics which make them more suitable for this type of viewer. Again, they also have certain drawbacks. A neutral beam splitter is necessarily very inefficient because of the light it must waste, and often suffers (as does a dichroic) from unwanted reflected images and astigmatism. Pellicle mirrors - thin beam-splitting membranes stretched over a metal frame ground to optical tolerances - are a solution to the multiple image and astigmatism problem but are

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quite sensitive to vibration and are virtually impossible to clean. Despite these difficulties, if enough light is available, such a coaxial system offers one distinct advantage in that a common point in each frame is projected through the lens at the same field angle. Where registration and freedom from distortion and color fringing are of such critical importance, the coaxial projection system is required. This is the type of system which will be used in the proposed viewer, incorporating specially designed pellicle beam splitters.

The optical system for the proposed viewer is shown schematically in Figure C-3. A total of six separate films can be displayed in many combinations, including stereo or superposition with flicker (or "blink") capability, natural color, or false color. A unique beam-splitter system allows a single lens to handle a pair of films without undue loss of flexibility in scale matching. The basic configuration is similar to a successful experimental integrating enlarging printer (Fig. C-4) designed

STAT and built by [redacted]

On the short conjugate side of each lens, another beam splitter and another gate have been added in the proposed viewer.

A great variety of operational modes is possible. For example, gates 1, 2, and 3, which are all parallel to the screen, can be loaded with color-separation photography and accurately matched for scale and registration while producing with filters a "natural" color picture, false or complementary color display, or Land color. Gate 4 could contain, say, an infrared record; camouflage detection film in gate 5; and aerial color film in

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gate 6. These records in gates 4, 5, and 6 would be available for reference or comparison with each other or with the separation records.

Very striking effects can be achieved through the Land technique by superimposing an infrared (or long wavelength) record with a red (or short wavelength) record, using color filters in one or both projection systems. Infrared reflection associated with growing plants and trees, for example, can be vividly displayed in a familiar green state or in an attention-getting red. The possibilities of camouflage detection in this mode are numerous.

C-2 LIGHT SOURCE AND CONDENSER ASSEMBLY

Each projection station is provided with its own ~~100~~ 1000-watt tungsten lamp and condenser optics. Each lamp is adjustable to provide maximum uniformity of illumination at the screen. The condenser, which forms an image of the lamp at the projection lens entrance pupil, includes two plano convex glass elements approximately 7-inches in diameter and a spherical reflector.

To protect the film, a heat reflecting interference filter and a heat-absorbing filter are used between the two condenser lenses. Cool filtered room air is drawn into each condenser housing, and heated air is exhausted behind the lamp by means of a central externally mounted blower system. Such an arrangement provides adequate cooling with minimum heat rise though the optical path, while at the same time introducing much less vibration than internally mounted fans.

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C-3 PROJECTION LENS

Three modified Wollensak f/4 10-inch focal length Raptar Telephoto lenses are used in the viewer at 5X magnification. These lenses provide a shortened optical path while maintaining a minimum of 8 lines/mm at the screen at this magnification. The lenses are mounted in iris barrels to provide some illumination control, but more importantly to help correct, through depth-of-focus, minor scale differences which may exist between formats in each projection pair. Screen illumination is primarily controlled by a variable transformer in each lamp circuit, and benefits derived from a stopped down projection lens are applied toward scale correction as required, and where illumination levels permit it. This feature, while not strictly necessary with very careful selection of input camera lenses and format sizes, does allow an additional degree of freedom and somewhat increased flexibility.

C-4 VIEWING SCREEN

To minimize depolarization effects a 24- by 24-inch LS 75ST Polacoat stereo rear projection viewing screen is used. The glass screen is mounted in a metal frame which can be tipped outward at the front of the console for cleaning. Screen replacement, if required, is accomplished by opening the self-locking rubber bezel by which it is attached to the frame. Tilt and z-axis adjustments of the screen are possible.

Screen illumination, E, in foot candles, is given by the expression

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$$E = \frac{\pi\left(B + B_R\right) T}{4\ (f/mo)^2 (M + 1)^2}$$

where

B = brightness of the source in candles/ft^2

B_R = brightness of reflected lamp image

T = total transmission of the system, expressed as a percent, which includes the following losses:

t_c = transmission of condenser and platen optics, including heat filters

t_f = transmission of color filters

t_p = transmission of polarizers

t_B = transmission (or reflection) of beam splitter

t_L = transmission of projection lens

t_A = average transmission of aerial photographs

$T = t_c \times t_f \times t_p \times t_B \times t_L \times t_A$

M = magnification

f/mo = relative aperture of the projection lens

A sample calculation shows an approximate value to be expected for illumination at the screen from one gate under the worst conditions, that is with polarizers for stereo

$B = 1.6 \times 10^6$ candles/ft^2 for tungsten at 3200° K

$B_R = 1.6 \times 10^6 \times 0.75 = 1.2$ candles/ft^2

$M = 5X$

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$f/mo = f/4$

$t_c = 0.65$

$t_f = 0.30$ (blue filter)

$t_p = 0.40$

$t_B = 0.07$

$t_L = 0.80$

$t_A = 0.50$ average highlight areas

$T \approx 0.0024$

$$E = \frac{\pi\left[\left(1.6 \times 10^6\right) + \left(1.2 \times 10^6\right)\right] (0.0024)}{4\ (4)^2\ \ (5+1)^2}$$

$E \approx 10$ foot candles

With a screen gain, G, of 4.5, which is the approximate brightness enhancement of Polacoat screens, when the viewing direction is parallel to the incident ray being viewed, the screen brightness B_s becomes

$$B_s = E \times G$$

$$= 10 \times 4.5$$

$$= 45 \text{ foot lamberts}$$

This represents the worst condition, and also is the value for a single station. The combined effects of six stations in stereo operation would probably produce over 400 foot lamberts due to

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increased red and green transmission. To illustrate further the wide range of illumination which can be encountered, with no polarizers, no color filters, and an open gate, the screen brightness would be about 675 foot lamberts per gate or 4050 foot lamberts for all six gates.

Thus, while the overall light efficiency is very low, the expected screen brightness level is very good and will in fact have to be reduced for many combinations of films and filters.

C-5 FILTERS

A filter wheel is located near each projection lens. Unmounted Wratten gelatin filters are used to preclude focusing differences due to glass thickness variations. Each wheel will have six apertures to include red, green, blue, and clear filters, with two others which can be inserted according to the type of data reduction required. The appropriate filter is positioned electrically by the operator with a switch at the control panel. To permit maximum flexibility of filter selection, only a single drive button for each wheel is used, instead of six push buttons. The operator simply pushes the button long enough for the drive motor to rotate the wheel to the proper filter where a spring-loaded ball-detent positions the filter in the optical path.

C-6 SHUTTER

A double-bladed "bow-tie" shutter is located adjacent to each filter wheel. A three-position switch provides the following modes of operation:

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(1) Open - for uninterrupted projection of the image onto the screen.

(2) Closed - for aiding registration of multiple images one gate at a time.

(3) Flicker - alternate opening and closing of shutters on one, two, or all three projection lenses in synchronization with each other. The shutters, or flicker wheels, are rotated by pulse-driven step motors which permit adjustment of the phase and rate of rotation of the wheels. This allows a fairly slow "blink" capability of about 1 cps, or a higher frequency of 10 cps or more for luminance matching.

C-7 STEREO COLOR VIEWING

For full color stereo viewing, each projection lens would project a monochromatic stereo pair which had been produced by a single camera. For example, projection lens A in Figure C-3 projects simultaneously the images from gates 1 and 4 through one color filter such as red. Projection lens B might display a green stereo pair and lens C a blue pair. Polarizers are inserted manually into each of the condenser systems, and the operator wears Polaroid spectacles.

To aid registration in this mode, only one projection system is used initially. Usually the green projector B, comprising gates 2 and 5, is turned on and the films adjusted until a good stereo presentation is made. Then one lamp, say at gate 5, is turned off so that the red image from gate 1 and the blue image

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from gate 3 can be accurately registered with the green image from gate 2. The 1, 2, and 3 gates are turned off and the corresponding red and blue images in gates 4 and 6 are aligned with gate 5.

Once the color stereo display has been made through the methodical registration procedure, false color presentations can be effected. This color mode may bring about enhanced detection capability, while the stereo helps keep in perspective an unfamilar color combination.

While alignment of six separate images for full color stereo is necessarily a somewhat painstaking and involved procedure, monochromatic stereo is simple and extremely useful. A great deal of information is available from a single band stereo pair which is normally projected as black and white. This is a more useful mode for rapid screening of many frames of film and helps pinpoint areas to be examined thoroughly by all the techniques available with the viewer.

C-8 FILM TRANSPORT

The film transport system used for each gate of the proposed viewer is a modified version of the one used in [redacted] production model "Junior" Film Reader (Fig. C-5). Drive for the scan mode is provided by a bidirectional motor-driven capstan. Drive motor velocity is precisely controlled by a velocity servo, directed by a joystick on the operator's control panel. STAT

A single joystick controls all six film transports, one at a time, through a switching circuit activated by the selection of

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the desired transport control button. The joystick is interlocked with the viewer's air/vacuum supply such that the vacuum is automatically turned off and the levitating air supply is turned on whenever the control is moved away from the stop position. This sequence is automatically reversed when the control is returned to the stop position. Supply and takings torque motors are used for film tension control and for braking.

Depending upon the mode of operation, particularly full color stereo, it is sometimes necessary to thread some of the films with the emulsion side facing the platen. This is to avoid mirror reversion which might otherwise occur. Since all the black- and-white or separation films to be projected are contact positive transparencies, scratching is not quite the concern that it would be if first generation negative masters were used. Nevertheless, the film transport is so designed that only the outer edges of the side of the film (usually the emulsion) facing the lens is in contact with the rollers. All surfaces in contact with the opposite side of the film are designed to minimize film scratching.

C-9 X-AXIS SCAN

The servo-driven, rubber-coated capstan drives the film along the x-axis at any selected speed in the range of 0.1 inch per second to 100 feet per minute in either direction, controlled by the joystick. Constant film tension is maintained by the action of two torque motors - one for the supply spool, the other for the takeup spool - whose torques are controlled as functions of the

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sensed film diameter. The torque of each motor is determined by the instantaneous voltage applied to it through a powerstat whose wiper arm is positioned by a film diameter sensing arm and roller.

C-10 THE y-AXIS TRANSLATION

The joystick which controls the polarity and magnitude of the voltage applied to the capstan drive motor, providing bidirectional x-axis control, also provides bidirectional control of the transverse support carriage in the y-axis or at right angles to the scan direction. The platen, film, and film transport will move approximately $\pm$ 2-1/4 inches in the y-direction so that any point in the field can be brought to the optical axis.

C-11 ROTATION

Each film transport platen and transverse movement system is supported by a rotary table (Fig. C-6) whose axis of rotation coincides with the optical axis of the projector. The table is rotated by a variable speed motor and timing belt. Since the primary use of rotational control is for the accurate registration of images, this motion is restricted to $\pm$ 10° from the x-axis, thereby simplifying the system and avoiding mechanical interferences between gates. A spring-return rotary switch on the control panel is used to control the polarity and rotational speed of the drive motor. The six-button switching unit which actuates the joystick according to the selected projection gate also controls the rotation switch.

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C-12 FILM PLATEN

The platen selected for the proposed viewer is a highly efficient vacuum type developed by [ ] and used with considerable success in production models of the [ ] "Junior" Film Reader. STAT STAT This platen (see Fig. C-8) has a continuous vacuum groove around the periphery of the format area. Quick and reliable pulldown of the film is ensured by the weight of the holddown plate's floating inner frame, whose two Teflon-coated rails apply gentle pressure to the outer edges of the film. Air is used for rapid breakaway, and to levitate the film during transport. With the air/vacuum switch off, it is possible to scan with optimum focus as the rails hold the film in intimate contact with the platen.

To eliminate the need for film threading at the platen assembly, the entire holddown plate (including the floating inner frame and two idler rollers for accurate edge guiding of the film) can be hinged upward for film insertion.

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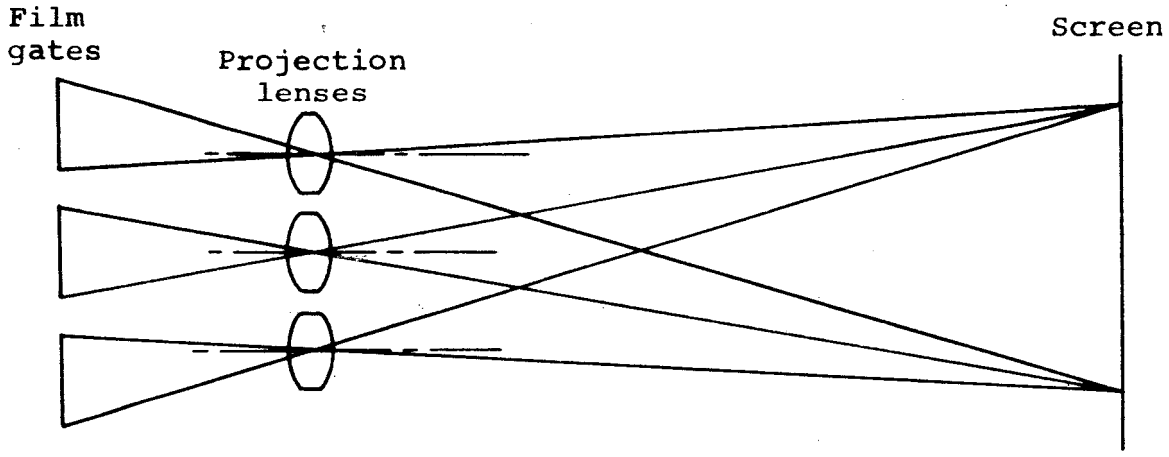

Figure C-1.- Off-axis convergent projection system.

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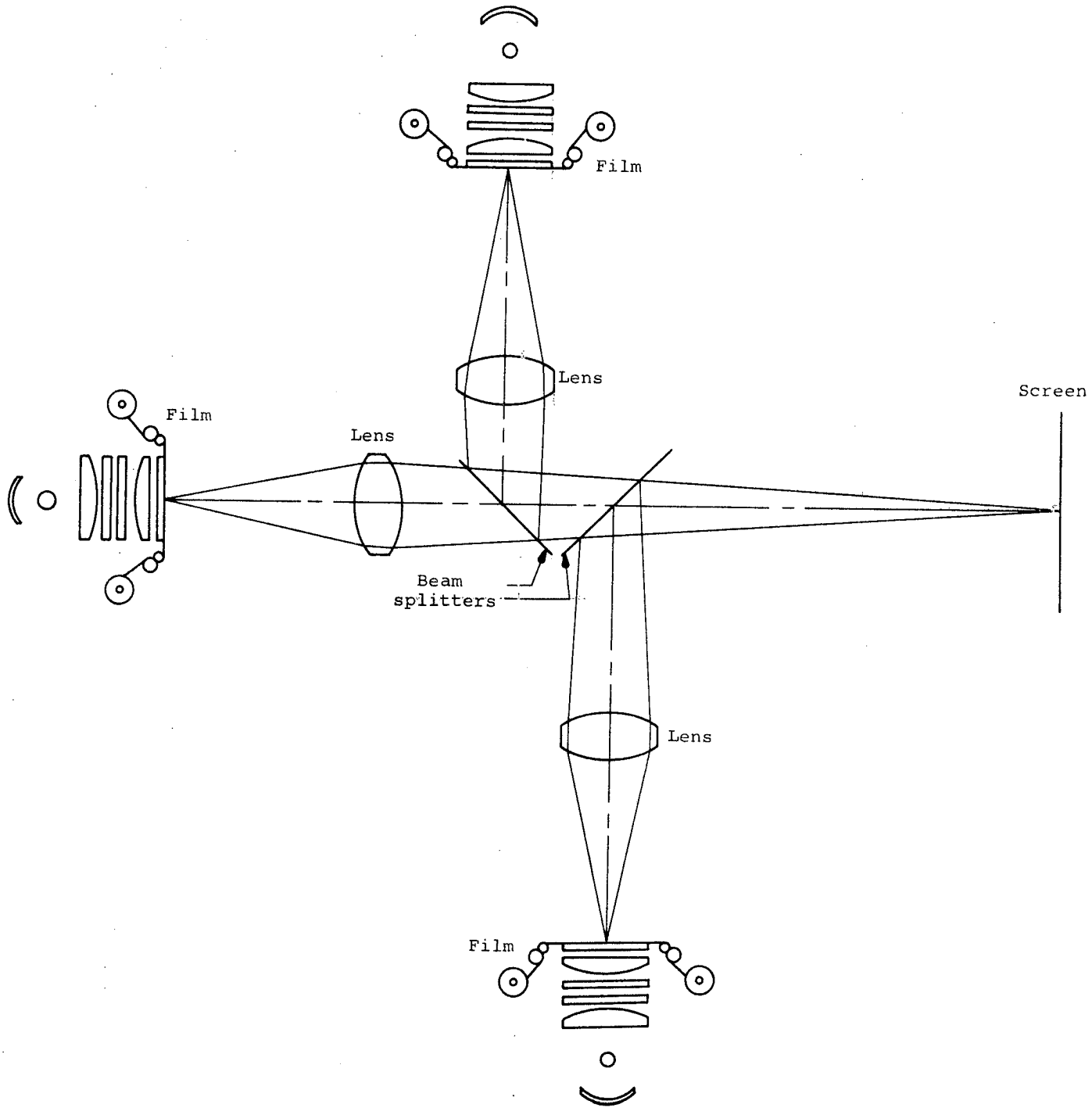

Figure C-2.- Coaxial projection system.

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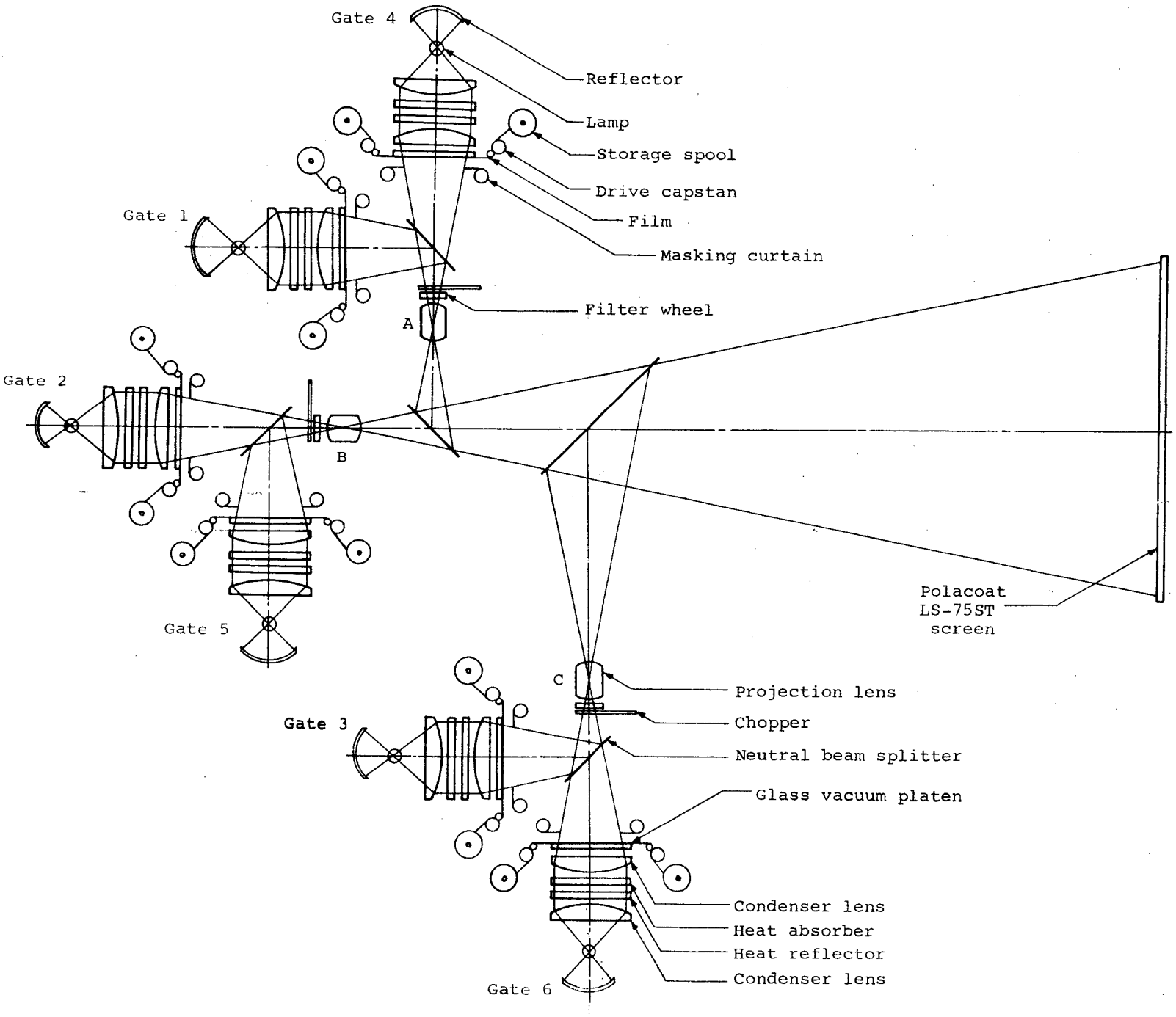

Figure C-3.- Multigate coaxial projection viewer.

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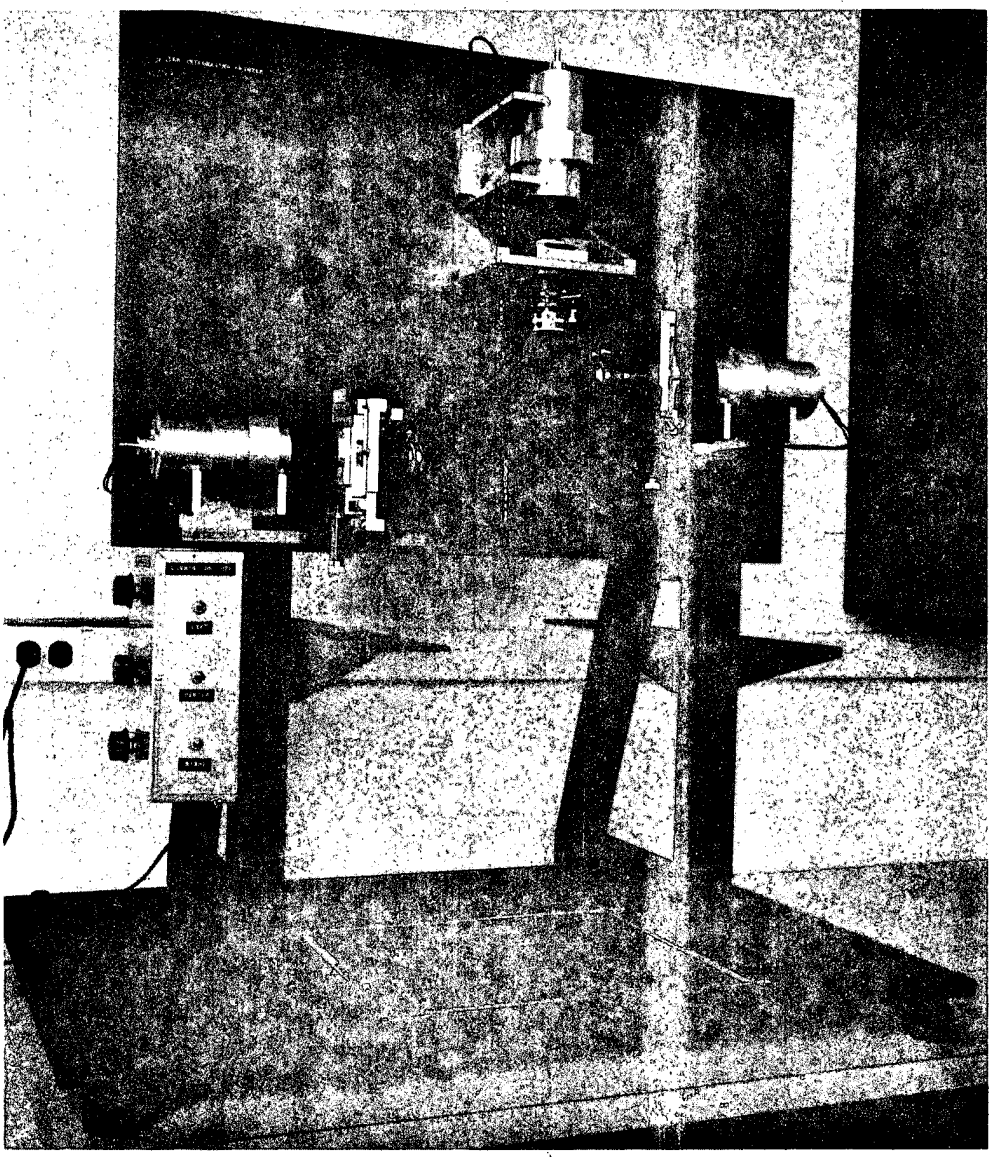

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Figure C-4.- Integrating enlarger.

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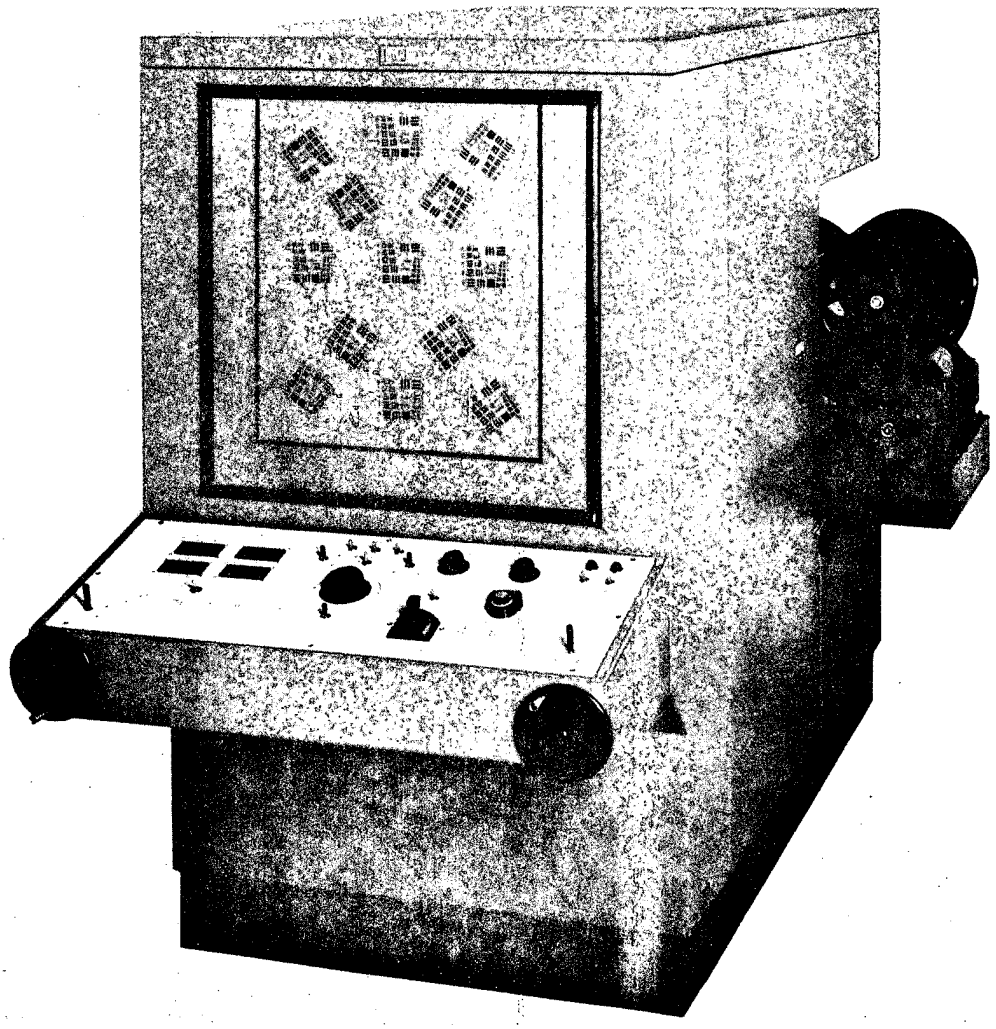

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STAT Figure C-5.- [redacted] "Junior" film reader.

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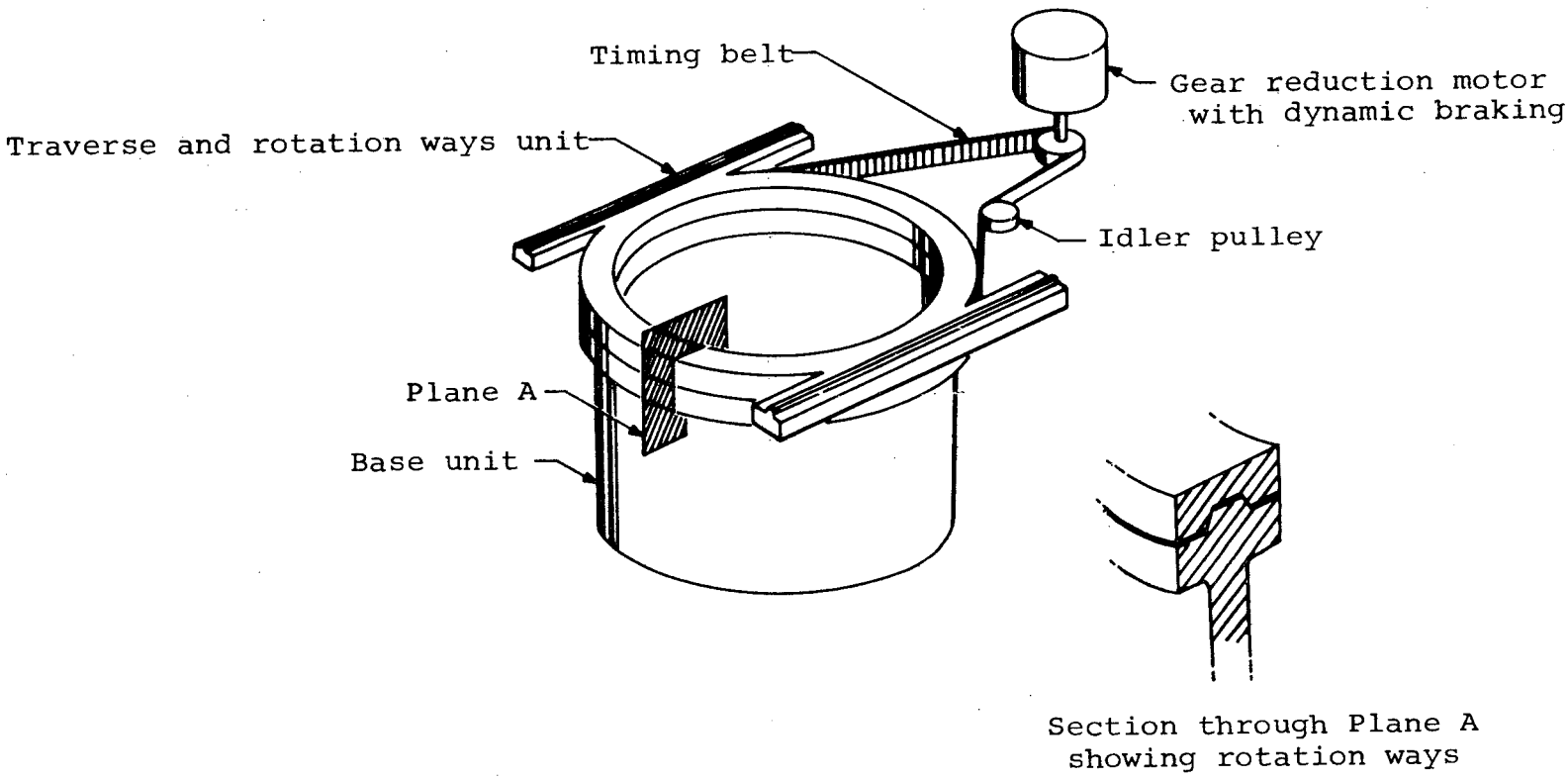

Figure C-6.- Image rotation component.

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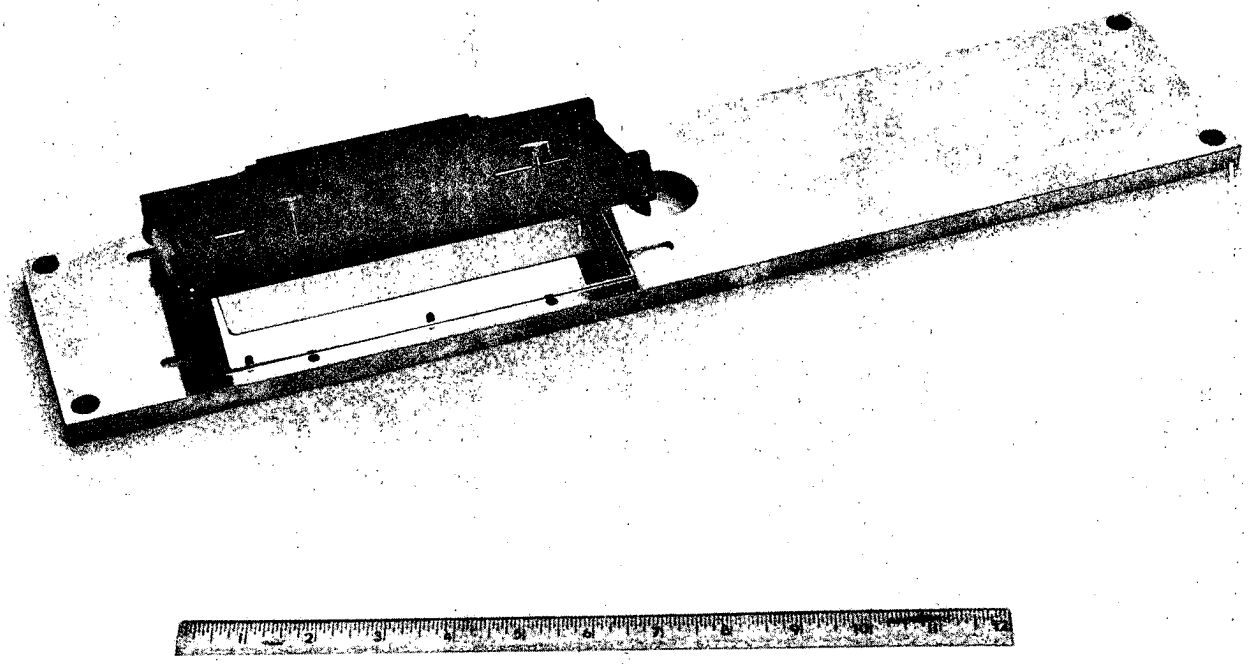

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STAT Figure C-7.- [ ] production model vacuum platen.

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